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POPULATION ESTIMATION OF ASIATIC LIONS[1]

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(*With seven text-figures*)

Key Words: *Panthera leo persica,* mark-recapture, individual identification, Gir lions.

Applicability of vibrissae spot pattern for individual identification of Asiatic lions *(Panthera leo persica)* was validated in wild and captive lions. We used computer simulation models to work out the applicability of the Lincoln-Peterson model and its sample size requirements for varied population sizes. The model recommended marking over 30% of a hypothetical population of 250 lions to obtain a desired level of accuracy (CV < 20%) for estimating population size. An appropriate experimental design was then developed for such a census in Gir National Park and Sanctuary. The vibrissae technique was utilised for individual identification of 80 wild lions in Gir for conducting a mark-recapture census. The Peterson population estimate of lions (excluding cubs < 18 months) in Gir was 222. The standard deviation using Chapman (1951) estimator was ±54.5 lions. A separate analysis of the male and female populations estimated 74±17 males and 167±67 females. We also estimated the mean (201 lions) and standard deviation (±23) by a modified Jack-knife technique. The Forest Department of Gujarat concomitantly conducted a labour intensive *total count* of lions using bait for over three days. The *total count* of lions in Gir National Park and Sanctuary (excluding cubs) was 94 males, 110 females (204 total). Analysis of past several years census data suggests that the lion population in Gir has been increasing with an r = 0.022 ($P<0.001$, $R^2=0.96$). We recommend the use of the vibrissae identification method as a tool for monitoring, estimating populations, and to develop more sophisticated models for evaluating survival and movement of lions.

Introduction

Population estimation of wide ranging carnivores has always been a challenge to wildlife managers. Several approaches have been tried for estimating large carnivore numbers. These include pug-marks (Das and Sanyal 1995, Gore et al. 1993, Panwar 1979, Smallwood and Fitzhugh 1993, 1995), track counts (Palomares *et al.* 1996, Van Sickle and Lindzey 1991), scent-plots (Knowlton and Tzilkowski 1979), mark-recapture (Garshelis 1992, Karanth 1995, Karanth and Nicholes in press), radio-telemetry and intensive study in small areas, densities of which are then extrapolated to estimate total population (Fuller 1989). In case of endangered carnivores, population estimates need to be precise and accurate, since a small decline in such a population could prove disastrous (Taylor and Gerrodette 1993, Caughley 1994). Methods for

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censusing endangered carnivores need to be practical and cost effective with regard to prevailing socioeconomic conditions of the region.

Tiger *(Panthera tigris)* census in India is done using the pug-mark technique (Choudhury 1970) whose accuracy and precision were questioned (Karanth 1987). Karanth (1995), and Karanth and Nicholes (in press) have used camera traps to estimate tiger numbers within intensive study areas in tiger preserves. Objective, accurate and precise census techniques for large carnivores are urgently needed. In this paper, we evaluate the available data on Gir lion populations and currently used census technique, and demonstrate the use of sighting-resighting population estimation (Pollock *et al.* 1990) as an alternative for monitoring and estimating numbers of the last remaining population of Asiatic lions in the Gir Forest of Gujarat, India. The sighting-resighting estimate of lions in Gir was done concomitantly with the five-yearly *total count* of lions that is conducted by the Gujarat Forest Department (Singh 1995, 1997). This provided a unique opportunity to compare the statistical estimates obtained by the mark-recapture technique with the *total counts* as a point estimate.

Methods

Total Counts of Lions

Since 1963, the Gujarat Forest Department has estimated lion numbers in Gir about every five years. For the 1995 census, lions were baited with live domestic buffaloes for three consecutive days throughout the entire lion range (over 1,800 km^2). Over 250 buffaloes were used and about 1500 man-days consisting of forest staff and volunteers were employed in conducting this massive census operation. Most lions in Gir were used to killing livestock and readily took buffalo bait. A daily record was kept of all lions that fed on (or visited) the baits. After accounting for possible double counts, the maximum number of lions recorded on any single day was considered to be the total population.

Precision of Population Estimates

Judging from the Forest Department records for the past several years, we speculated that the lion population in Gir was close to 250 individuals. We modelled a scenario wherein a population of 250 lions was declining at a rate of ten percent per year. Since there was no way of estimating accuracy or precision of the *total counts* reported by the Forest Department, error bars with these estimates could not be generated. Population estimates for large cats having a coefficient of variation less than 20% are difficult to achieve in wilderness areas (Karanth 1995, Karanth and Nicholes in press, Smallwood and Fitzhugh 1995). To evaluate the effect of precision and time intervals between consecutive counts on the practical utility of population estimates, we generated 95% confidence intervals on the modelled population estimates using a coefficient of variation of 20%. We compared 95% confidence intervals on subsequent population estimates to determine if the estimates differed.

Individual Identification of Lions

Pennycuick and Rudnai (1970) developed a technique for identifying individual African lions *(Panthera leo leo)* based on vibrissae spots. Further, they calculated levels of probability of encountering another lion with the same vibrissae pattern within a given population.

The vibrissae spot method is based on variation in the spot patterns of the top row (row A) of spots with reference to the second row (row B) of spots (Fig. 1). For a detailed description of the technique see Pennycuick and Rudnai (1970). We collected data on vibrissae patterns of 40 wild and 34 captive Asian lions with the aid of a 15 to 30X spotting scope and occasional photographic records using a 300-500 mm lens. Spot patterns were recorded on graph paper (Fig. 1) where each square provides a potential

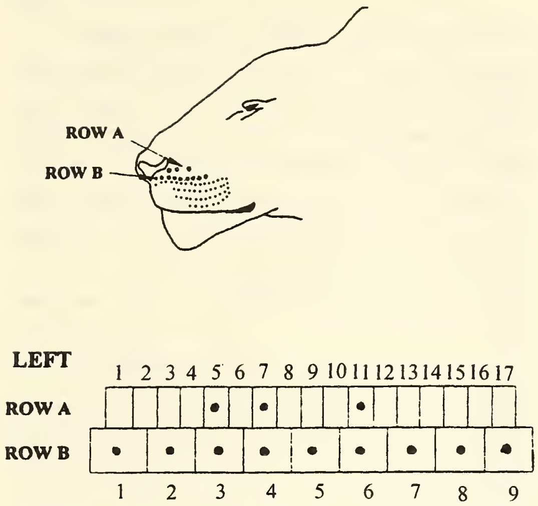

Fig. 1 : Left profile of a lion showing whisker patterns used for individual identification. Graphical representation of the same pattern is presented below (after Pennycuick and Rudnai 1970)

location of a spot in Rows A and B. Thus Row B could possibly have a maximum of 9 spots, while row A could have a maximum of 17 spot positions.

Data on the location of the lion, age group, sex, pride composition, and any additional identifiable marks on the body like notches in the ear, and permanent scars were recorded. The above data from Asian lions were analysed to test the validity of the assumptions of the method and reliability of unique identification.

Sight-Resight Population Estimation

Sight-resight population estimate is based on the Lincoln-Peterson model (Pollock *et al.* 1990). The model is based on 2 capture (sighting) sessions: (i) Sighting and individual identification of a random sample of lions (nl). (ii) Subsequent sighting survey, wherein another random sample of lions is identified (n2) and within this sample, lions that were also sighted in the first survey are counted as "recaptures" (m). The model has several assumptions that need to be satisfied to estimate lion numbers without bias and with good precision:

(i) Geographic and demographic closure of the Gir lion population, (ii) correct identification of each lion with no mistaken identity and (iii) all lions must have the same, independent probability of being sighted (Otis *et al.* 1978).

Population estimation (N) is based on the principle of dilution:

$$N = \frac{(n1\ n2)}{m} \quad \text{..........equation 1}$$

An unbiased estimate of N is obtained by (Otis *et al.* 1978):

$$\tilde{N} = \frac{(nl + 1)\ (n2 + 1)}{(m+1)} - 1 \quad \text{........equation 2}$$

and its variance was estimated as (Chapman 1951):

$$\text{Var}\ \tilde{N} = \frac{(nl+1)\ (n2+1)\ (nl-m)\ (n2-m)}{(m+1)^2\ (m+2)} \quad \text{..........equation 3}$$

where nl = sample of first sighting and identification
n2 = sample of second sighting and identification
m = number of lions from the first sample (n1) that were again sighted in the second sample (n2) (resighted).

Since we included the entire Gir Forest (National Park and Sanctuary) covering an area of over 1400 km^2 as our study area, the population could be considered as geographically closed. Two small lion populations have been established outside of the Gir Reserve after 1990 by dispersing lions (Singh 1997). These were in Girnar numbering close to 10, and the coastal forests of Kodinar numbering approximately 20 lions. Movement between these populations and the Gir protected area could not be ruled out. Even if such movements did occur during the course of this study, the numbers involved would be quite small.

Session 1, marking lions, effectively lasted for six months in the summer and winter months of 1994. The second session was of a much shorter duration of 18 days and coincided with the total count exercise conducted by the Gujarat Forest Department in May 1995. The two sampling sessions were spaced about 10 months apart. Inevitably some mortality of the marked lions would have occurred in this time frame and affected the precision of our mark-recapture estimate. Since mortality was likely to be greatest amongst young cubs (Ashraf *et al.* 1995), we sampled lions that were older than eighteen months of age.

Lions are known to be territorial (Johnsingh and Chellam 1991, Joslin 1973, Chellam 1993). Prides are found to be composed of related females, their young and sub-adult male offspring. Adult males are usually found as coalitions of 2-3, solitary, in temporary association with prides or with single females in oestrus. This social organization precludes the assumption of random mixing of lions and independent sighting probabilities. We attempted to address this issue by sampling areas at random for intensive searches for lions (White and Garrot 1990). Lion distribution, in summer, was determined to a great extent by availability of water (Chellam 1993). We stratified Gir Protected area into three strata; i) eastern Gir, ii) western Gir and iii) central Gir. We mapped all perennial sources of water in Gir and randomly selected 2-3 water sources within each stratum as centres for intensive search. Eight to ten days were spent in each of these areas looking for lions, using pug-marks, kills, roars and fresh scats as clues. Mainly, fresh pug-marks were located early in the morning, the tracks followed and lions located. Lions were then approached to within 20-40 m on foot and the whisker patterns determined. To increase sample size of individually identifiable lions, we opportunistically sampled any lion that we encountered within the study area.

The second sampling (n2) was more intensive and covered a short interval of eighteen days. It coincided with the Gujarat Forest Departments *total count* using baits. During this sample we spent approximately equal time and effort in western, central and eastern Gir. We also used a live goat to lure lions into becoming stationary till we had completed identifying their vibrissae patterns. The majority of our samples were obtained from lions on bait. A wireless radio network in Gir was our source of information for lions that were located during the *total count* exercise and we rushed to as many locations as possible with two vehicles that worked independently.

Sample Size Determination

It was important to estimate the minimum number of lions that should be sampled for achieving a desired precision for a population estimate. We performed computer simulations by varying the sample size for the first session (n1) between 20 and 80 lions and the sample size for the second session (n2) between 30 and 80. The simulation was run 500 times for each combination of nl and n2 for a hypothetical population of 250 lions. Recaptures were determined and population size (N) computed by equation 2.

Since we were also interested in the general application of sight-resight model to other large carnivore population we ran another simulation where the total population size was 50, 100 and 250 individuals. Most wildlife preserves in India are likely to have populations of tigers and leopards *(Pantherapardus)* ranging between the population sizes that we used for the simulations. For these simulations we sampled 25 and 50% (n1 + n2 = 25% and 50%, with n1 = n2) of the entire population. Coefficient of variation for the population estimates were computed and used as an index of precision.

Other Analyses

We performed 1000 modified jack-knife estimates (Krebs 1989) by randomly dropping 2 to 9 lions from nl and n2, determining m and computing N for each run. We plotted the N estimates and their standard deviations obtained from the simulation to ascertain the effect of reducing sample size on parameter estimate.

RESULTS

Total Counts

It was not possible to estimate the precision of the *total counts*. The counts were likely to report minimum numbers. The technique was extremely labour intensive and expensive. It may become increasingly difficult in the future to use live bait due to animal rights awareness amongst the public. Since the same method for obtaining *total counts* has been employed since 1968, it would be possible to use the *total counts* for the past years as an index for Gir lion population trends (Fig. 2).

The lion population in Gir was increasing with an $r = 0.022$ ($\lambda = e^r = 1.0224$) for the past 25 years ($p = 0.0006$, $R^2 = 0.96$). There was a tendency towards achieving an asymptote by the population in 1995. However, the next *total count* will show whether the Gir lion population has stabilized or continues to increase.

Precision and Time-frame of Population Estimates

Population estimates with a 20% CV were unable to detect any change in the modelled declining lion population (95% CI) after 5 years, or even when the lion population was reduced to half its size (Fig. 3). A ten percent annual decline for a large carnivore is a serious cause for concern. In case of highly endangered species like the Asiatic lion, estimates need to be more precise so as to detect small changes in a

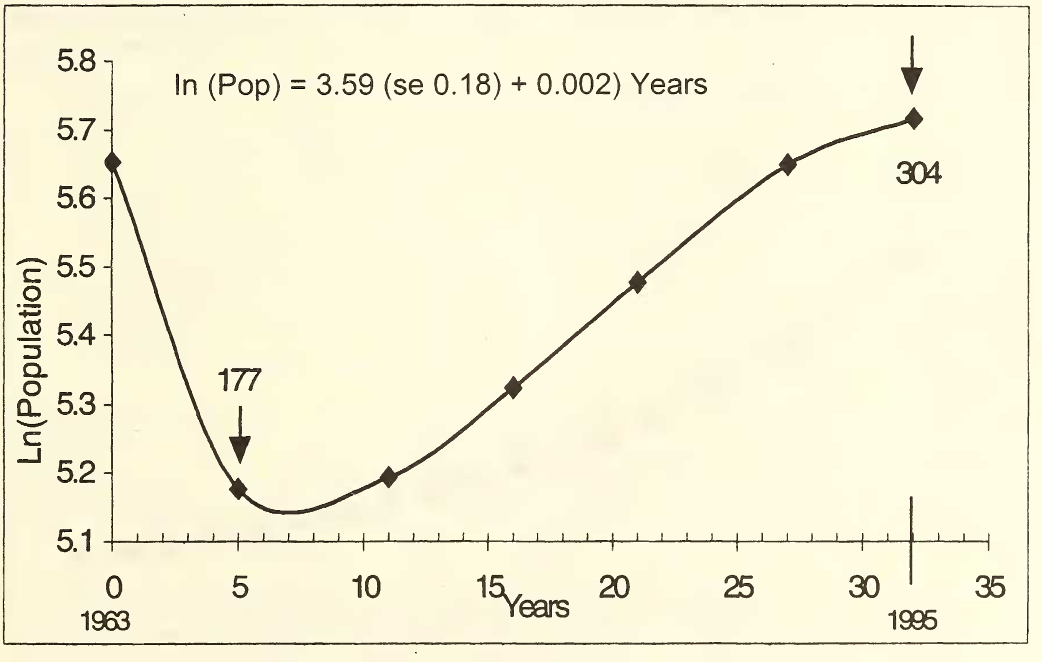

Fig. 2: Trends in the lion *total counts* in Gir between 1963 to 1995. The inset reports regression results for log transformed *total counts* between 1968 and 1995.

population. The current time frame of five years interval between total counts (the only form of population monitoring currently employed in Gir) is too long an interval for monitoring a highly endangered carnivore population.

Individual Identification of Lions

The maximum number of spots observed in row A for any lion were four. The whisker patterns of right and left side differed in the total number of spots (Table 1). We therefore used the left and right sides independently for calculating frequencies and probability of spots occurring in each position (Table 2).

The probability of finding any specific spot pattern on any one side of a lion would be the total product of probabilities of occurrence of each spot in row A (p_i) observed on that lion and the probabilities of spots not occurring (q_i) in the remaining potential spot positions. Thus the probability of a lion having 2 spots in row A on the left side at locations 3 and 5 would be:

TABLE 1

FREQUENCY OF DIFFERENT NUMBER OF VIBRISSAE SPOTS OBSERVED IN ROW 'A' ON LEFT AND RIGHT SIDES FROM A SAMPLE OF 74 LIONS.

No. of Spots in Row A	Left Side	Right Side
0	1	10
1	43	35
2	22	21
3	6	7
4	2	1

χ^2 between left and right sides = 8.62, $p < 0.05$.

P (left) = p3 x p5 x q1 x q2 x q4 x q6 x q7 x q8 x q9 x q10 x q11 x q12 x q13 x q14 x q15 x q16...........equation 4

Values for p_i and q_i were computed from a sample of 74 lions (nl number of wild lions and captive Asiatic lions) (Table 2).

The frequency of left and right sides having a particular number of spots in the sample population of 74 lions was compared with the aggregate probability of all combinations having that number, as calculated from equation 4 and Table 2 (Table 3). We observed that two spots occurred more often than expected on both sides

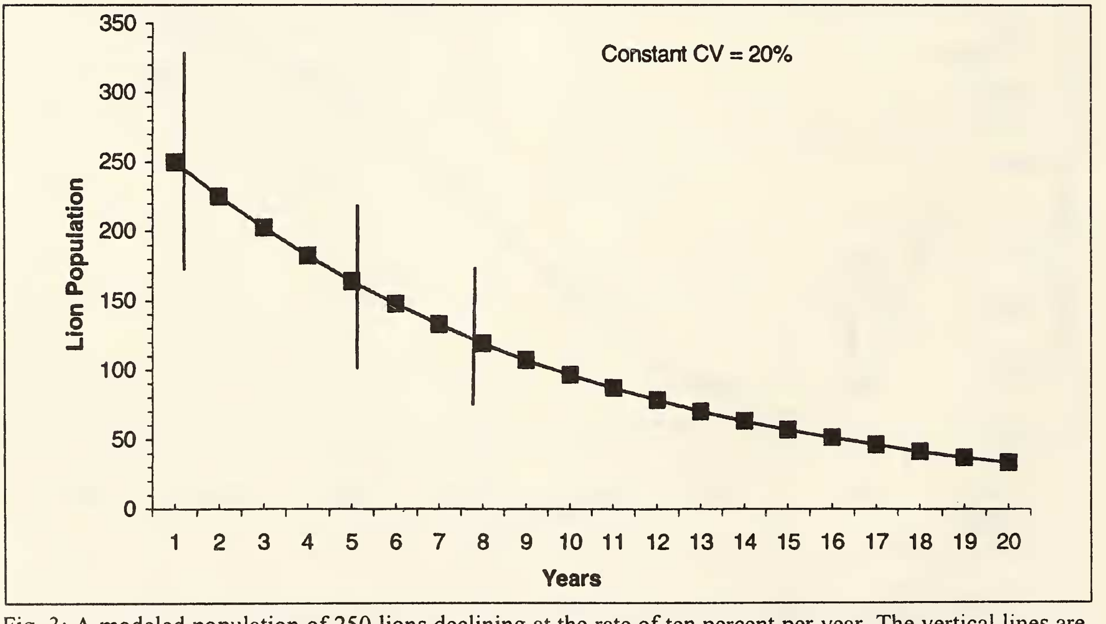

Fig. 3: A modeled population of 250 lions declining at the rate of ten percent per year. The vertical lines are 95% confidence intervals on population estimates (using CV=20%).

TABLE 2
FREQUENCY (Frq.) AND PROBABILITY (p) OF OCCURRENCE OF SPOTS AND PROBABILITY (q) OF SPOTS NOT OCCURRING AT EACH POSITION ON THE LEFT (Lt) AND RIGHT (Rt) SIDE IN ROW A. (COMPUTED FROM A SAMPLE OF 74 ASIATIC LIONS)

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lt. Frq.	0	0	5	6	15	20	11	9	10	7	6	10	11	3	0	0
Lt. Prob. p	0	0	0.068	0.018	0.202	0.27	0.149	0.122	0.135	0.095	0.081	0.135	0.149	0.041	0	0
Lt. 1-p=q	1	1	0.932	0.919	0.798	0.73	0.851	0.878	0.865	0.905	0.919	0.865	0.851	0.959	1	1
Rt. Frq.	1	0	5	3	12	16	11	12	3	13	7	10	7	1	0	1
Rt. Prob. p	0.014	0	0.068	0.041	0.162	0.216	0.149	0.162	0.041	0.176	0.095	0.135	0.095	0.014	0	0.014
Rt. 1-p=q	0.986	1	0.932	0.959	0.838	0.784	0.851	0.838	0.959	0.824	0.905	0.865	0.905	0.986	1	0.986

and that one spot occurred more often than expected on the left side of our sample lions (Table 3). The occurrence of no spots on the left side was lower than expected in our sample. This lack of independence of spot patterns would reduce the level of reliability of individual identification of lions.

The probability that more than one lion has a particular pattern in a population of 300 lions is given by:

$\Pi_x = p^x .(1-p)^{M-x} .M! / X!(M-x)!$

$\Pi_0 + \Pi_1 = (1-p)^M + Mp\,(1-p)^{M-1} > 1 - \varepsilon$

Π_x = Probability that x individuals have a particular pattern; ε = Error term

p = Probability of pattern occurrence

x = Number of individual with particular pattern

M = Total population (300)

INFORMATION CONTENT

$I = -\log_2 p$

I = Information content in bits

To match the reliability criteria we would expect this probability to be $\varepsilon < 0.05$ i.e. there would be less than five percent chance of another lion having the same identifying characteristics in a population of 300 lions. Considering the information from row A alone, all but one lion met the stringent criteria of reliable identification. We combined information of row A patterns with information on the number of spots in row B and the sex of the lion. With this combination of information the possibility of confusing 2 lions in a population of 300 lions was, on an average, one in ten thousand (Fig. 4).

In accordance with the information theory (Pennycuick and Rudnai 1970), for a lion to be identified definitively from amongst a population of 300 lions, the individual must convey a minimum of nine bits of information. All sampled lions met this criterion and most had over 15 bits of information (Fig. 5).

TABLE 3
OBSERVED AND EXPECTED NUMBER OF VIBRISSAE SPOTS ON LEFT AND RIGHT SIDES OF 74 LIONS WITH DIFFERENT NUMBERS OF SPOTS

No. Spots	No. Possible Combinations	Aggregate Prob. Left Side	Expected Left Side	Actual No. Left Side	Chi Square Contribution	Aggregate Prob. Right Side	Expected Right Side	Actual No. Right Side	Chi Square Contribution
0	1	0.1 893	14	1	12.07	0.228	16.872	10	2.79
1	14	0.3448	25	43	12.96	0.336	27.084	35	2.30
2	91	0.1289	9.54	22	16.27	0.031	2.294	21	152.03
3	364	0.1336	9.89	6	1.53	0.109	8.066	7	0.14
4	1001	0.042	3.106	2	0.39	0.03	2.22	1	0.67
Total					43.22				157.95

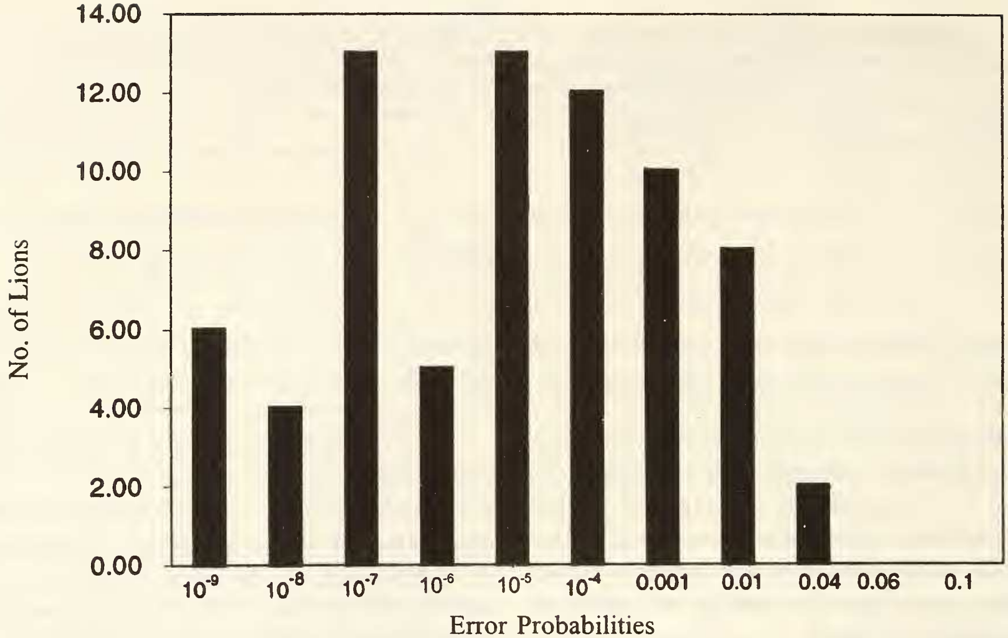

Fig. 4: The distribution of sampled lions with the various probabilities of reliable identification in a population of 300 lions after considering information in spot patterns in row A, number of spots in row B and the sex of the lion.

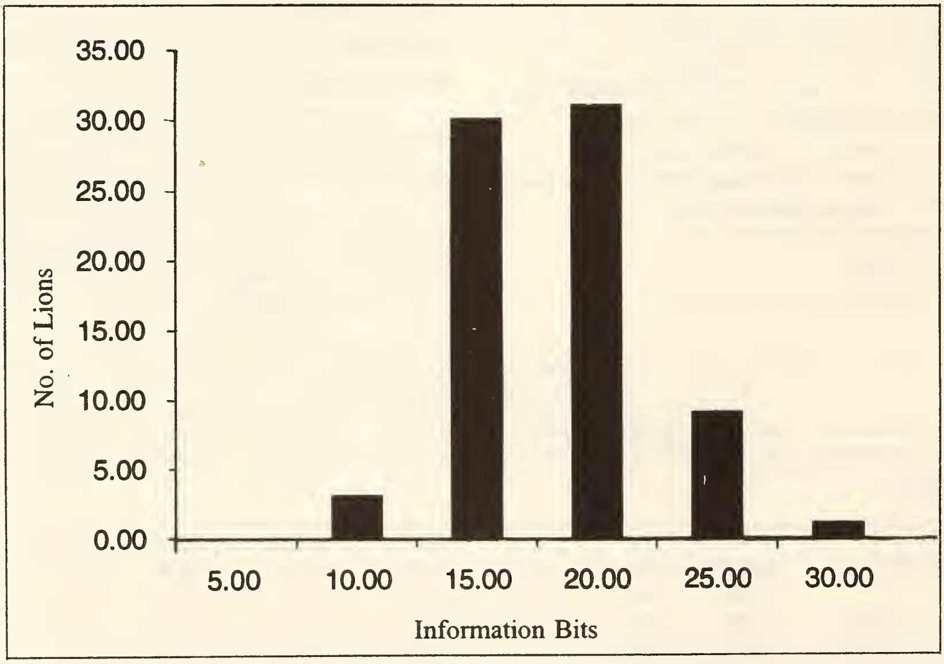

Fig. 5: Information bits from row A spot pattern, number of spots in row B, and sex of the sampled lions.

Sample Size Estimation

Our simulation results showed that to obtain a meaningful estimate of population size we needed to sample over 80 lions from a hypothetical population of 250. The results of the simulation were less sensitive to different magnitudes of nl and n2 as long as the sum of nl and n2 remained constant. The greater the magnitude of nl+n2, the higher was the precision of the estimate. For a given sum of nl and n2, minimum variation in parameter estimates was obtained when nl and n2 were of equal magnitude.

In the case of varying population sizes (50, 100, 250) where a constant proportion was sampled (constant sampling effort), the % CV was lower for larger populations than smaller populations for the same sampling effort. This suggests the need for more intensive sampling in smaller populations to obtain a similar level of precision in population estimates (Fig. 6).

Population Estimation

The number of lions sighted and identified for the first sample (n1) were 40. The second sample (n2) consisted of 48 lions. The number of recaptures m, exact matches, were 8 lions. We were uncertain regarding the resighting of one lioness due to a difference of a light spot seen during the second sampling. Considering the sex, location and pride composition of this lioness, it seems very likely that this was indeed a recapture and the spot was missed during nl session (marking). All computations were done considering m to be 8 as well as 9 (Table 4). A separate analysis of the male and female populations estimated 74 (sd 17) males and 167 (sd 67) females (using m=8).

The simulations using the modified jack-knife estimator provided an unbiased estimate of the lion number. However, precision decreased with decrease in nl and n2 (Fig. 7). This result also agreed with the results of our

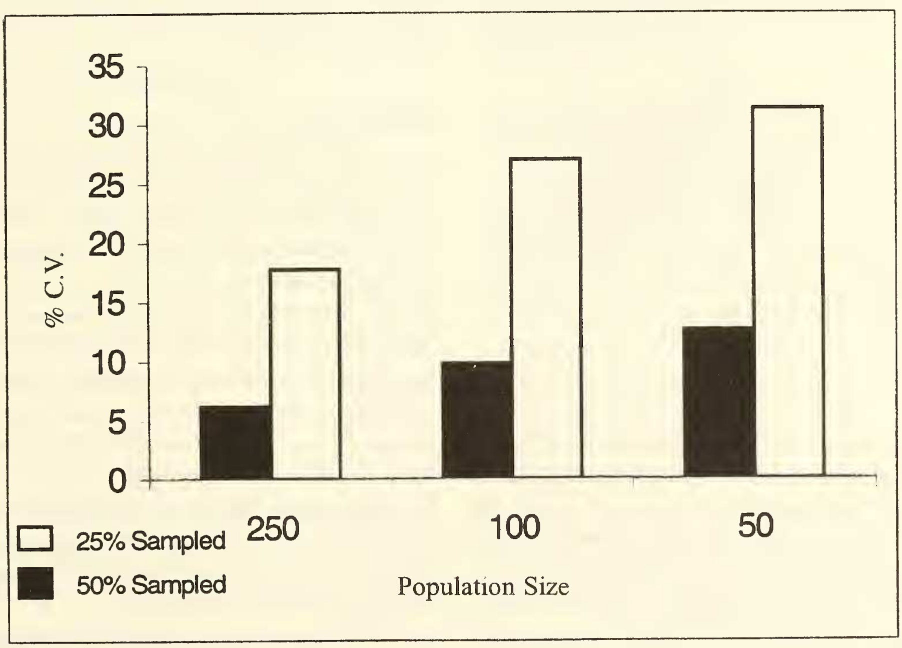

Fig. 6: Precision of population estimates (%CV) in relation to sampling effort (proportion of population sampled) and population size.

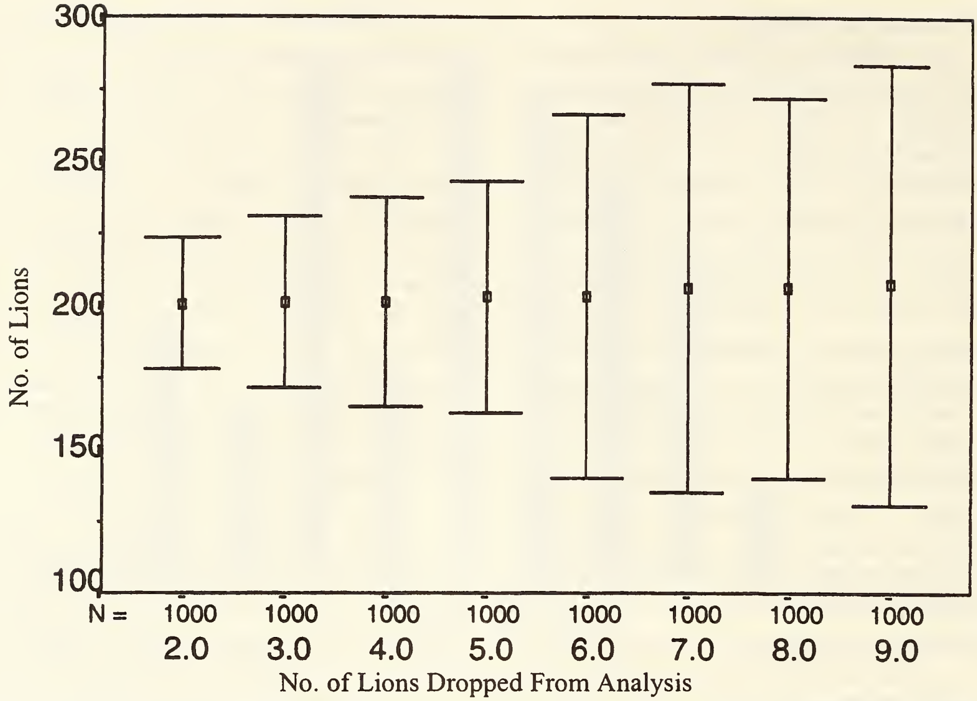

Fig. 7: Modified Jack-knife estimates of the lion population obtained by randomly dropping 2-9 lions from n1 and n2 and population size estimated for each run. The error bars are standard deviations obtained from 1000 simulation runs of each scenario.

TABLE 4
POPULATION ESTIMATES OF ADULT LIONS IN GIR FOREST, GUJARAT, 1995

Model	Population Estimate		Standard Deviation		% CV	
n1=40, n2=48	m=8	m=9	m=8	m=9	m=8	m=9
Lincon-Petersen	222	200	56	47	25	23.5
Modified Jack-Knife	224	201	37	23	16.7	11.4
Total Count	204					

simulations for estimating sample size (Fig. 6). Both the models agreed with regard to population estimates that ranged between 201 to 224 lions (Table 4). The modified jack-knife estimates had a lower coefficient of variation (Table 4) in comparison to the Chapman (1951) estimator. All estimates included the Forest Department's *total count* of 204 lions as a point estimate within one standard deviation of the mean.

DISCUSSION

Total Counts

The data for the population estimates used for the analysis of population trend were obtained from literature and reports (Dalvi 1969, Joslin 1973, Chellam 1993, Singh 1997). The total count method inherently precludes any estimate of precision or accuracy of the population estimates. The tendency of reporting an increasing population in subsequent censuses, for political reasons, may have been a source of bias in the reported total counts. We can only speculate that since the method used for all the counts between 1968 and 1997 were the same, biases (if any) in the estimates would be similar, and therefore total counts would at best be a good index of the population trend of lions in the Gir Protected Area.

Several government and non-government organizations, reputed naturalists, and wildlife scientists were invited by the Forest Department to participate in the total count exercise conducted in 1995. Since three of the senior authors participated in this exercise, we are in a position to complement its sincerity and sheer magnitude of effort that was invested by the Department during the data collection phase. However, none of the invited agencies or individuals were involved in the analysis of the data on the total counts. Lack of transparency at this crucial stage was arguably the major drawback of the 1995 total count and probably also of earlier counts.

Assumptions of the Mark-Recapture Model

Computer simulation results for estimating mountain sheep *(Ovis canadensis)* numbers, with various degrees of aggregation by mark-resight estimates, have shown that violation of the independent sighting assumption results in lowered precision of estimates, while accuracy and confidence interval coverage were relatively unaffected by aggregation (Neal *et al.* 1993). The strategy of randomly searching pre-determined areas for lions would, to some extent, ensure equal probability of sighting different lions from the Gir population (White and Garrot 1990). We did observe heterogeneity of sighting probability between individual lions. The lions of western Gir were more conducive to permitting close approach for individual identification, while those of eastern Gir were relatively skittish and more aggressive. This behaviour was likely due to the western Gir lion population being habituated by exposure to tourism. During the entire study, we came across four lions that did not permit us to ascertain their individual identity. One lioness we tracked early morning kept moving, and after following her for 2 km on foot we lost her. The other three were males that were extremely aggressive and did not permit us to approach sufficiently close on foot to ascertain their identification. Heterogeneity of sighting probabilities produces a negative bias on population estimates (Neal *et al.* 1993, Seber 1982).

Even though our analysis suggests non-independence of spot patterns (Table 3), we believe that the combination of spot patterns, unique markings, age and sex information of Gir lions were adequate to uniquely identify each lion in the gir population. Rudnai and Pennicuick (1970) have shown that the vibrissae spots do not change at least over the period of 19 months. In the case of Asian lions, vibrissae spots did not change for the captive lion population in the Safari Park in Gir and Sakkarbag Zoo at Junagadh over the span of one year. Tthus, the vibrissae spot patterns could be considered to be permanent at least over the period of the current sampling (one year).

We were uncertain regarding the resighting of one lion due to a difference of a light spot seen during the second sampling. This suggests that even though the vibrissae pattern along with other natural markings was found to have sufficient information for unique individual identification of lions in Gir, there existed a possibility of observer errors in quantification of vibrissae patterns. Errors in identification would also affect the population estimates.

Population Estimates

The highest precision was obtained by the modified jack-knife estimate which had the lowest standard deviation. However, the CV was still over 10% (CV = 11.4 to 16%) and would not therefore meet the rigorous criteria of detecting a 10% decline between years (Fig. 3) (Taylor and Gerrodette 1993). The lower value of the 95% confidence interval on the smallest population estimate (Lincoln-Peterson with m = 9, Table 4) was 108 lions, while the upper value of the 95% confidence interval on the largest population estimate (modified jack-knife, m = 8) was 297 lions. We believe that the adult lion population in Gir protected area was between 108 and 297 in 1995 with 95% certainty.

This study exemplifies the need for large samples for precise estimates using mark-recapture models. Sampling effort would need to be disproportionally larger for smaller populations (Fig. 6). Lions are relatively easy to sample and "mark" and such large samples could be made a reality. However, the practical use of these models for estimating tiger and leopards remains questionable.

There would be a gain in population estimate precision if the Jolly-Seber model (Pollock *et al.* 1990) or its modified versions, which include several continuous marking and capture sessions, were used (Anderson and Burnham 1994, Bowden and Kufeld 1995, Neal *et al.* 1993). Combination of mark-recapture models with other methods like radiotelemetry would go a long way in improving population estimates of large carnivores (Neal *et al.* 1993). Such models and combination of techniques would also enable the study of survival, mortality, and dispersion, in addition to estimating population size or density.

For a highly endangered large carnivore like the Asiatic lion, a continuous scheme for monitoring the lion population needs to be implemented. The estimation of the total numbers of lions may be inconsequential for detecting trends in the lion population (Eberhardt and Knight 1996, Karanth 1987, Karanth and Nicholes in press). Our simulation study suggests that the best current techniques used for estimating large carnivore numbers are likely to lack statistical power for detecting trends among populations. The monitoring scheme could be based on population indices and should have the statistical power of detecting slight changes in lion populations (Taylor and Gerrodette 1993). The monitoring program would enable timely management inputs in the form of rectifying measures for control of poaching, disease and other sources of mortality. Our study suggests the possibility of utilising the vibrissae pattern in comination with other information for reasonably accurate individual identification and monitoring of the Gir lion population on an annual basis. This technique of identification, coupled with more refined statistical models with multiple marking and capture sessions, would improve population estimates and provide additional information on the demography of Gir lions (Leberton *et al.* 1992).

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